Reclamation and Mitigation Measures
For
Downtown Kantishna Gravel Pit

A Report Prepared For:
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TABLE OF CONTENTS

INTRODUCTION ... 1
PROGRESSION OF PIT DEVELOPMENT ... 1
  Site Design ... 1
  Stormwater Runoff Mitigation ... 3
  Vegetation Clearing ... 3
  Stockpile/Process/Temporary Access Roads ... 6
MOOSE CREEK BRIDGE ... 6
  Flood Magnitudes and Elevations ... 7
  Bridge Alignment ... 8
  Encroachments ... 8
  Ice and Debris ... 9
  Types of Bridges ... 9
  Reclamation After Temporary Bridge Removal ... 10
PHASED GRAVEL EXCAVATION AND RECLAMATION ... 11
  Excavation ... 11
  Reclamation ... 11
ELDORADO CREEK RELOCATION AND RECLAMATION ... 12
  Channel Design ... 13
  Channel Construction ... 14
  Stream Channel Erosion Control ... 14
MOOSE CREEK BANK STABILIZATION ... 15
  Hydraulic Analysis ... 15
  Stream Channel Erosion Control ... 17
REFERENCES ... 19

Table of Figures

Figure 1. Downtown Kantishna area map.. 2
Figure 2. Initial mitigation measures for Downtown Kantishna gravel pit. 4
Figure 3 Detail 'A' showing stormwater runoff mitigation measures for site perimeter. 5
Figure 4. Access road construction and reclamation. 7
Figure 5. Detail 'B' showing relief culverts for bridge approach, and reclamation details. 10
Figure 6. Reclamation details of Downtown Kantishna gravel pit. 12
Figure 7. Typical bioengineered bank erosion control methods for Eldorado Creek reclamation. 16
Figure 8. Typical bioengineered bank erosion control methods for Moose Creek reclamation. 18

INTRODUCTION

A large area containing tailing piles and other ground disturbances from placer mining is being considered by park managers as a potential gravel source, due to the location along the park road and proximity to future gravel-intensive projects (Figure 1). Preliminary information on the development and restoration of this proposed gravel site was provided to the National Park Service (NPS) in a previous document (HMM, 2002). Subsequently, a need has risen for additional information which will describe the mitigation measures that would be used in the development and reclamation of the proposed Downtown Kantishna (DTK) gravel pit, in Denali National Park and Preserve. This information will be used by NPS in the preparation of the Denali Gravel Acquisition Plan.

The reclamation and mitigation actions described in this report are governed by various laws, regulations, and policies that apply to activities conducted in a floodplain, and construction activities that are classified as 'associated with industrial activities.' These include:

Clean Water Act and Amendments, P.L. 92-500
Executive Order 11988, Floodplain Management
Executive Order 11990, Protection of Wetlands
Procedural Manual #77-2 NPS Floodplain Management October 2002
Resource Management Plan, Denali National Park and Preserve
Environmental Assessment Reclamation of Mined Lands Program Denali National Park and Preserve May 2001

Of particular note is the long-standing NPS policy to preserve floodplain values and minimize potentially hazardous conditions associated with flooding. To implement NPS floodplain policy, proposed actions are classified into one of three action classes. Depending upon the action class, one of three "regulatory floodplains" applies (100-year, 500-year, or Extreme). If a proposed action is found to be in an applicable regulatory floodplain and relocating the action to a non-floodplain site is considered not to be a viable alternative, then flood conditions and associated hazards must be quantified as a basis for management decision making and a formal Statement of Findings (SOF) must be prepared. The SOF must describe the rationale for selection of a floodplain site, disclose the amount of risk associated with the chosen site, and explain flood mitigation plans. Actions such as excavating gravel from a floodplain, constructing a bridge to access a gravel pit, and relocating a stream need to be assessed by staff of the NPS Water Resources Division to determine whether or not they would meet the criteria for any of the three action classes.

PROGRESSION OF PIT DEVELOPMENT

Site Design

A complete engineering site survey needs to be conducted before any excavation or restoration operations begin. In addition to elevation surveys, vegetation, locations of

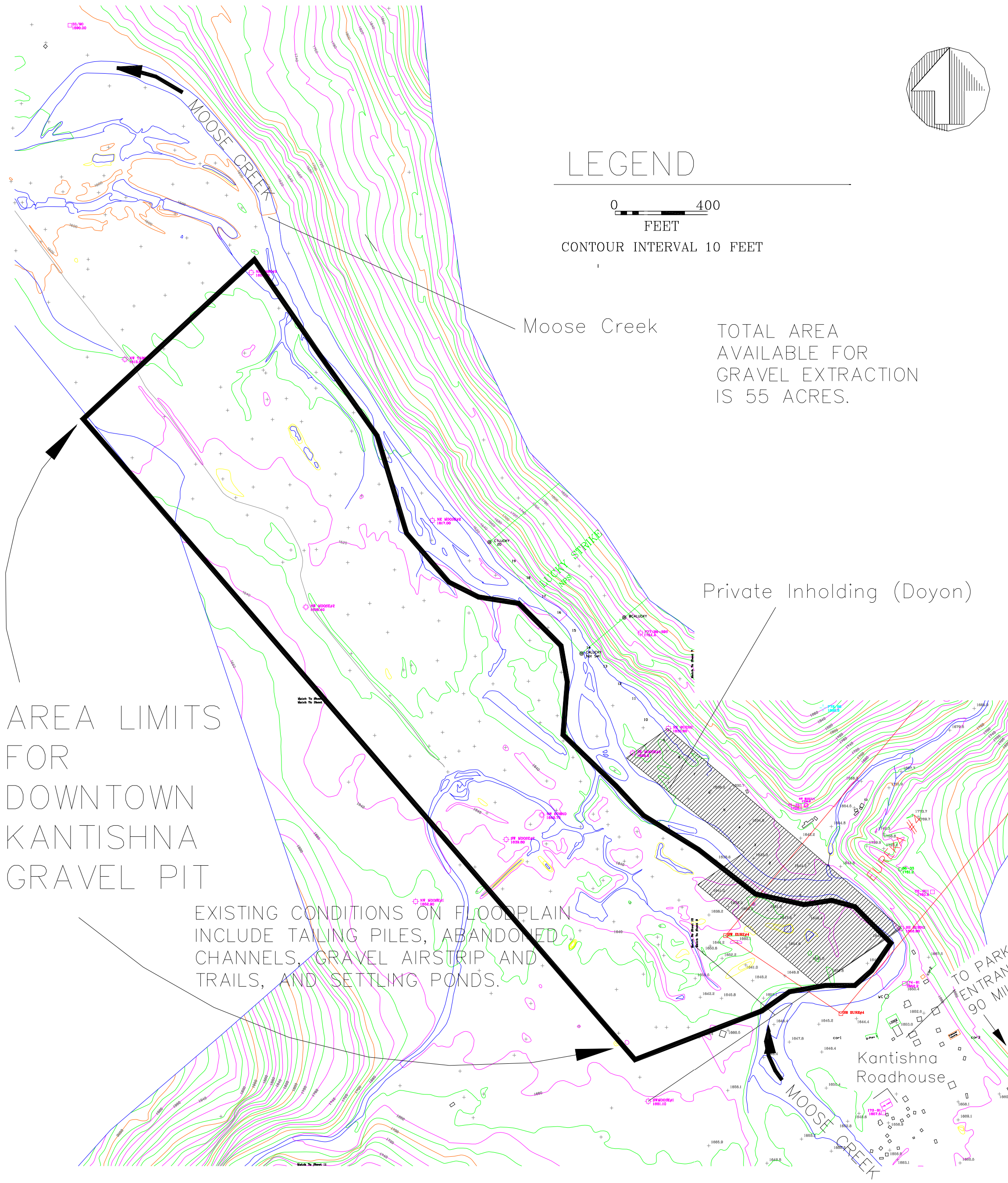

Figure 1. Downtown Kantishna area map.

organic overburden, and other habitat features should be located and mapped. An operational site plan is developed from this information. The site plan specifically outlines the order of operations, methods used, equipment used, mitigation and reclamation measures, and other items to insure observance with all compliance and planning documents. Based on the site plan, careful and thorough staking should occur on-site before any other action. Staking is used to provide visual and operational limits to boundaries for clearing, excavation, and reclamation activities.

Additionally, a precise survey of the private land parcel owned by Doyon Ltd., including boundaries and corners, must occur during this phase (Figure 1). This parcel must be clearly staked to avoid incursion by trucks or equipment during gravel pit operations.

Stormwater Runoff Mitigation
After the site design and staking, the first step is to install mitigative measures before any clearing or earthmoving operations begin. Mitigative measures are intended to control the overland stormwater runoff from all areas of clearing, grading, excavating, and draining prior to the start of those activities. These will be used downslope of all areas which will be disturbed during this project (Figure 2), and may be installed in phases to coincide with the phased clearing and excavation activities. These measures will include the installation of a silt fence, in conjunction with straw rolls (Figure 3).

Vegetation Clearing
The next step is to clear the vegetation mat and any other organic overburden from the surface in operational areas. In order to substantially reduce the problems of site erosion and subsequent sedimentation problems, the clearing operation, and associated gravel excavation operations, should occur as a phased operation. Sequencing a construction project reduces the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle tracking. In this manner, the least amount of vegetation necessary will be disturbed, resulting in reduced sediment runoff. A suggested phased approach is to divide the area into three sections, each section approximately 15-20 acres in size (Figure 2). Using the phased approach, site clearing operations, followed by gravel excavation activities, will occur in the area delineated Phase 1 only. Upon the completion of the gravel extraction for Phase 1, reclamation operations will commence. Following completion of reclamation, clearing operations will begin the area for Phase 2.

Though much of this site has been disturbed in the past 30 years, willow and alder have revegetated many of the areas, and need to be removed and disposed of or stockpiled for later use. Alder regrowth on tailing piles often occurs on bare ground, and there is essentially no organic overburden in the alder growth worth saving. The preferred method of disposal for woody vegetation in the park is to chip the wood using a powered chipper. The wood chips may then be used as mulch, or disposed of offsite. In the event that additional methods are required to facilitate disposal, some of the slash may be burned. Burning slash piles requires consideration of the effects of heavy and persistent smoke on the residents, visitors, and lodge activities within the Kantishna area. A number of items are required before burn operations may be conducted, including the approval of the DENA Superintendent, the completion and approval of an NPS burn plan, and a State of Alaska burn permit.

Organic overburden or soil (active layer) should also be salvaged and transplanted. Transplanted soil for reclamation purposes results in enhanced water holding capacities,

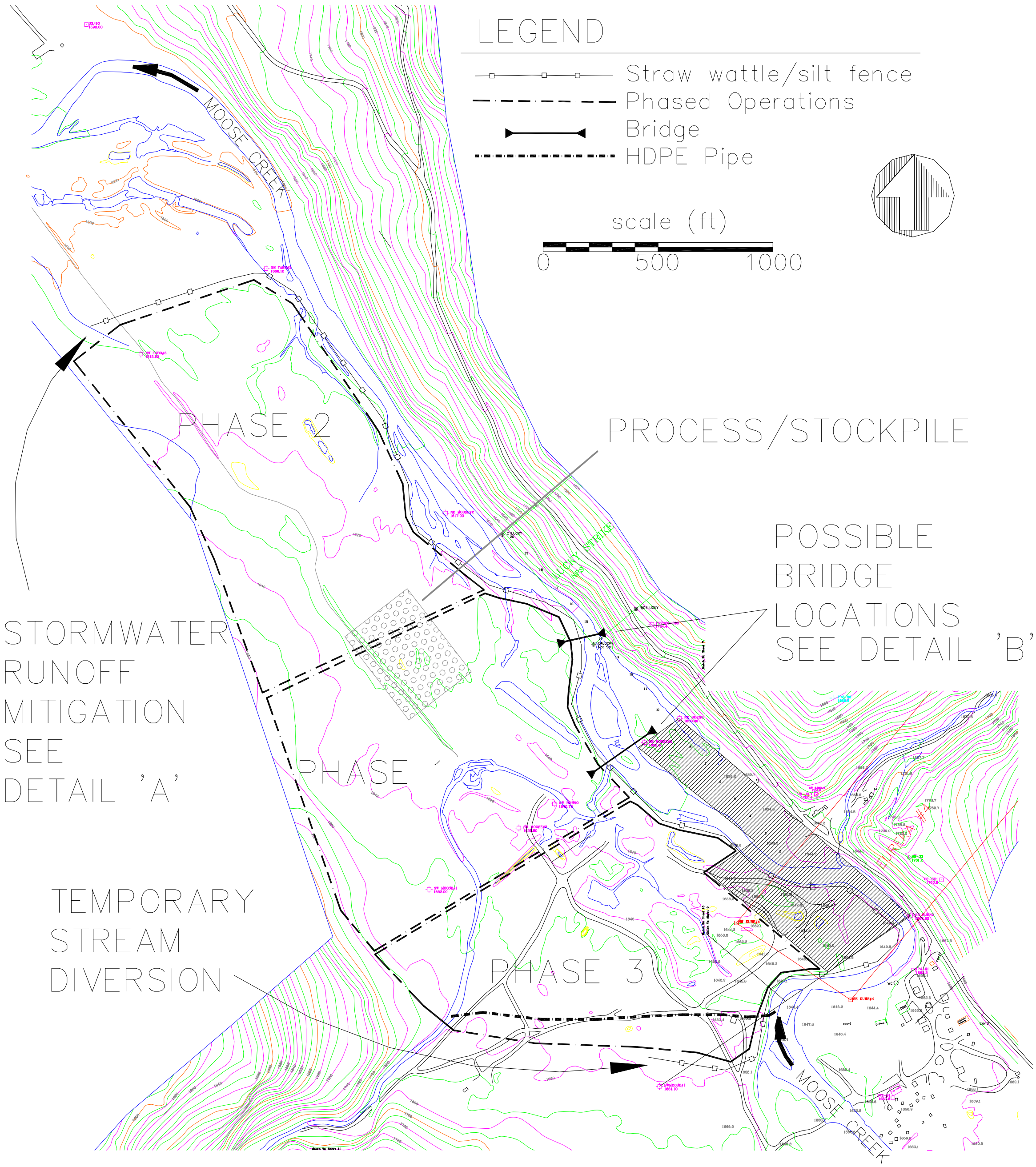

Figure 2. Initial mitigation measures for Downtown Kantishna gravel pit.

increased nutrient capital, and higher soil temperatures, which will facilitate seed germination, seedling survival and growth, and rooting. Proper procedures and care for salvaged soil is beyond the scope of this report but may be found in Densmore et al. (2000).

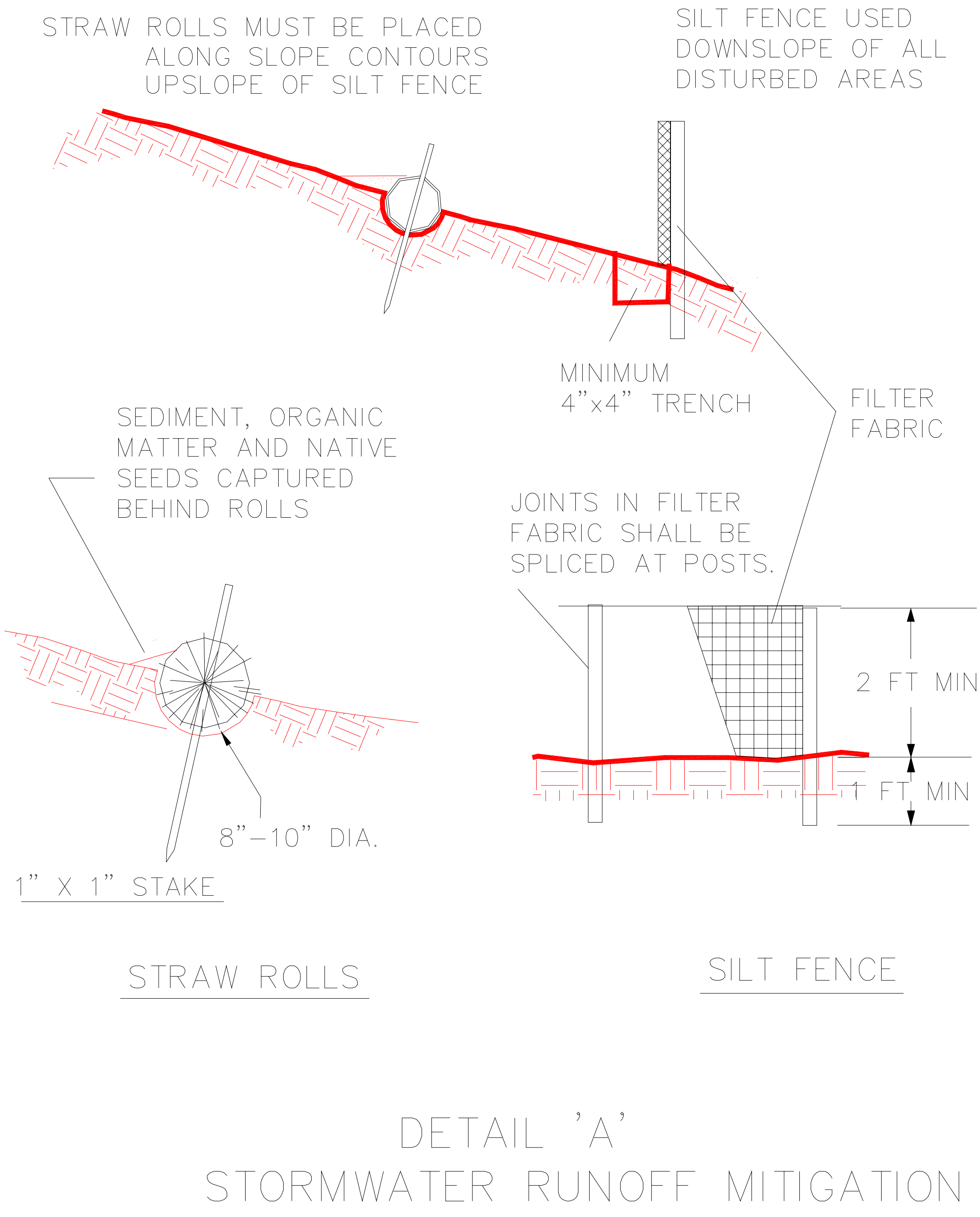

Figure 3. Detail 'A' showing stormwater runoff mitigation measures for site perimeter.

Stockpile/Process/Temporary Access Roads
After clearing, the next step is to develop the work/staging area and access roads. On firm ground, this should only require leveling the ground with a bulldozer. In soft areas, temporary access roads may have to be constructed. This will require a 6-inch depth of gravel base, applied over an engineering geotextile to provide separation between the subgrade soil and the gravel base. Using a geotextile reduces the amount of gravel required for road construction, and expedites the removal and reclamation of the road base (Figure 4).

The stockpile/process area, which could require between 3 and 4 acres, should be constructed on a firm, compacted subgrade. An interceptor swale would be constructed along the lower perimeter of the work/staging area to capture all sediment runoff and direct it to an erosion control facility. This facility would most likely consist of a settling basin, sized large enough to contain the runoff from a 10-year 24-hour storm.

Upon completion of excavation activities in each of the three phasing areas, all temporary construction roads shall be removed and rehabilitated. Additionally, at the completion of the project and removal/depletion of all available processed and stockpiled gravel, the work/staging area shall be removed and rehabilitated. This involves removing and leveling the gravel base, removing and disposing of all engineering geotextile, and ripping and roughening any compacted areas (Figure 4). Finally, the rehabilitated roads shall receive the same surface treatment for erosion control and revegetation as the rest of the project, as described below.

MOOSE CREEK BRIDGE

An important feature of this pit development is the requirement for a vehicle bridge to provide access over Moose Creek. Heavy equipment, possibly in excess of 80,000 pounds, would use this bridge to access the site, and transport processed gravel away from the site. According to the Water Resources Division-National Park Service, no standards are in place for hydrologic bridge design. Road construction within the National Park Service is generally guided by the Federal Highway Administration (FHWA).

The use of a ford for vehicle stream crossings, in lieu of a bridge, could place aquatic resources at risk. Based on a 55,000 cubic yard limit of usable gravel, it is estimated that 10,000 individual fords through Moose Creek would be made with 12-yard dump trucks and heavy equipment. Possible impacts to aquatic resources from such vehicle fords include: increased sedimentation, clogging of benthic invertebrate habitat, smothering of fish eggs, increased bed and bank scour and erosion, loss of fish and waterfowl habitat, and increased risk of water contamination by petrochemicals. Floodplain and wetland functions may be impaired or lost. Because of these impacts, it is unlikely that the Alaska Division of Fish and Game would issue a fish habitat permit, or that the NPS

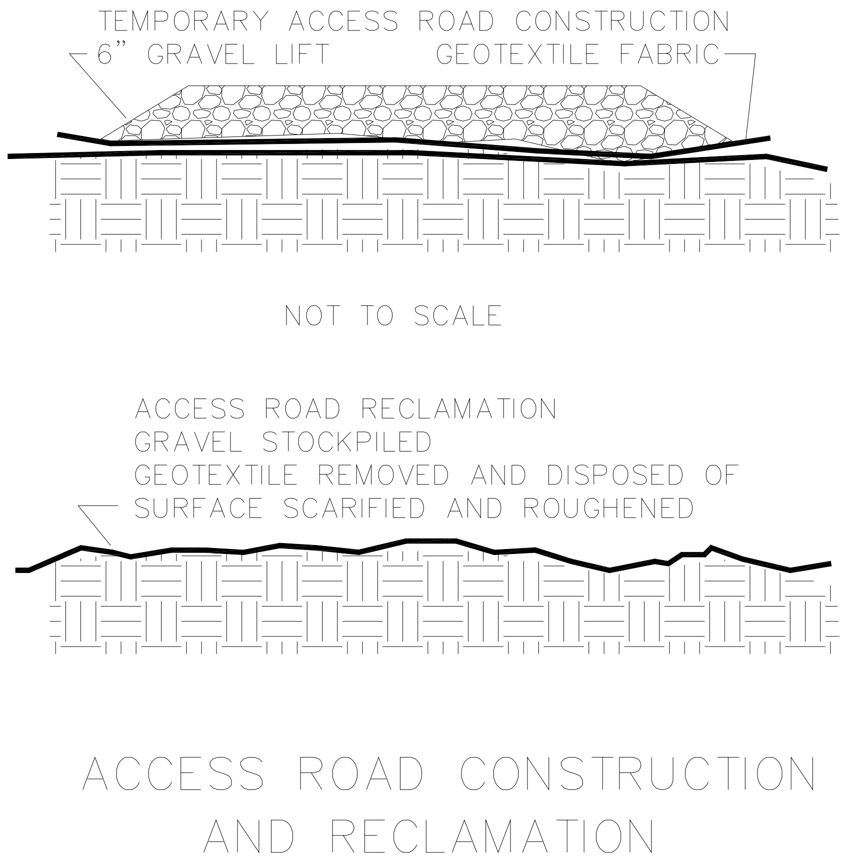

Figure 4. Access road construction and reclamation.

Water Resources Division would approve such a plan, due to the high number of crossings with heavy equipment during the project life.

It is recommended that, if an operational gravel pit is located on the west bank of Moose Creek, a well-engineered and constructed bridge should be required for all Moose Creek crossings. Bridge design will depend on the length of service desired from the structure (temporary or permanent bridge), and the desired level of impacts to the Moose Creek channel and floodplain. A few considerations for bridges are discussed below.

Flood Magnitudes and Elevations

As mentioned earlier, if this proposed action (bridge construction) is determined to be in a potentially flood-prone site, NPS regulations require that the regulatory floodplain that corresponds to the applicable Action Class should be delineated on a map of sufficient scale to meet all planning needs. The delineated floodplain should correspond to the elevation, on the land's surface, and location of the maximum extent of inundation by the regulatory flood. Flood magnitudes were estimated by NPS for several locations in the Moose Creek watershed using multiple-regression analyses from 260 gaged locations in Alaska and 72 gaged locations in Canada (Karle, 1998). Significant basin characteristics used in the regression equations are drainage area, mean annual precipitation, percentage of lakes and ponds, and mean basin elevation (Jones and Fahl, 1994).

Table 1-Magnitude and frequency of Floods For Moose Creek at the Moose Creek Bridge, Denali National Park and Preserve, Alaska.

Flood frequency (years)	Q_2 (cfs)	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}
park road bridge	961	1582	2008	2581	2977	3391	3758	4285

Though flood magnitudes are estimated, NPS currently lacks sufficient channel geometry information to estimate the elevation of a regulatory flood. This is a common procedure, in which cross-section data is acquired at a number of locations through the project area, and water surface elevations are estimated using a water-surface profile computational model for one-dimensional flow, such as HEC-RAS (USACE, 1998).

In addition to delineating the regulatory floodplain, floodplain management decisions are to be based upon information on the hydrologic and geomorphic processes and hazards associated with the location of the proposed activity. Flood hazard information should be developed and should include an analysis of flooding frequency at the proposed activity site, the probability of flooding over the planned project life, and the hydraulic attributes associated with the regulatory flood at the proposed activity site (flood depth and velocity).

After determining the Action Class and Regulatory Floodplain and evaluating hydrologic, hydraulic, and geomorphic hazards associated with the site of the proposed action, it is necessary to take effective actions to protect floodplain natural and cultural resources, and mitigate flood hazards to human life and property. Some considerations for floodplain protection and flood hazard mitigation follow.

Bridge Alignment

The horizontal alignment of a road determines where stream crossings will occur and where there will be transverse or longitudinal encroachments. As mentioned above, consideration of how the stream may affect the roadway, as well as how the roadway may affect the flow characteristics of the stream, must be considered. Slight changes in alignment can sometimes alter the flooding characteristics significantly.

The effect of the vertical alignment is significant. The vertical alignment, or profile, determines when, as well as where, the road will be overtopped. Not only does the profile affect the frequency of overtopping, but it also determines the level of upstream flooding.

Encroachments

Transverse encroachments are stream crossings, either normal or skewed, where there is some encroachment on the floodplain. The more common types of crossings involve construction of an approach embankment across a portion of the floodplain with a structure across the main stream. Occasionally, supplemental structures are located on the floodplain to accommodate overbank flow during flood events.

Possible environmental impacts from floodplain encroachment include downstream erosion, deterioration of fish and wildlife habitat, and loss of wetlands and riparian zones. Due to changes in the hydraulic profile, encroachment may also result in pier and abutment scour during flood events, as well as overtopping and erosion of approach embankments.

Ice and Debris

The most common causes of both ice and debris jams is a sudden change in cross section geometry in either width or depth or in stream gradient which changes the stream velocity. These changes tend to constrict or slow the flow, giving the ice or debris the chance to accumulate, bind together, and create a barrier. Ice and debris jams can be caused by a bridge or culvert opening being too small to efficiently pass objects such as ice chunks or logs. It is not easy to predict the size or occurrence of debris. Alternative measures include raising the roadway grade, and lengthening the bridge or increasing the culvert size. The effect of backwater from ice or debris jams on approach roadways and other features should also be considered. It is unlikely that the NPS Water Resources Division would approve a culvert structure, either permanent or temporary, on Moose Creek.

Types of Bridges

Bridges are constructed in many different manners, and the type of construction determines both the environmental impacts to the stream system, and the cost of the structure. For example, timber pile bridges may be low-cost and easy to install, but may be subject to ice jams. Steel bridges, either truss or girder, are more expensive but can span greater distances between abutments and/or piers.

Another factor to consider is the selected ‘design flood’ and the related total span distance and elevation of the bridge. Traditional bridge design resulted in bridge spans which were not much longer than the main channel width. Though cheaper, such a design can lead to increased impacts to the encroached floodplain, and result in a greater risk of overtopping the bridge deck. However, if a bridge project is temporary, then a decision may be made to accept a certain amount of risk, in terms of floodplain impacts and bridge overtopping.

One alternative to extending an open bridge span across a floodplain is to use relief culverts to pass large floods (Figure 5). Specifically, arch culverts are used where less obstruction to floodplains are desirable. Culvert inverts should be at the floodplain elevation. Multiple culverts should be used completely across the floodplain to keep constriction to a minimum. A complete hydraulic analysis should be conducted to insure flood passage and protection of the structure from backwater effects, etc.

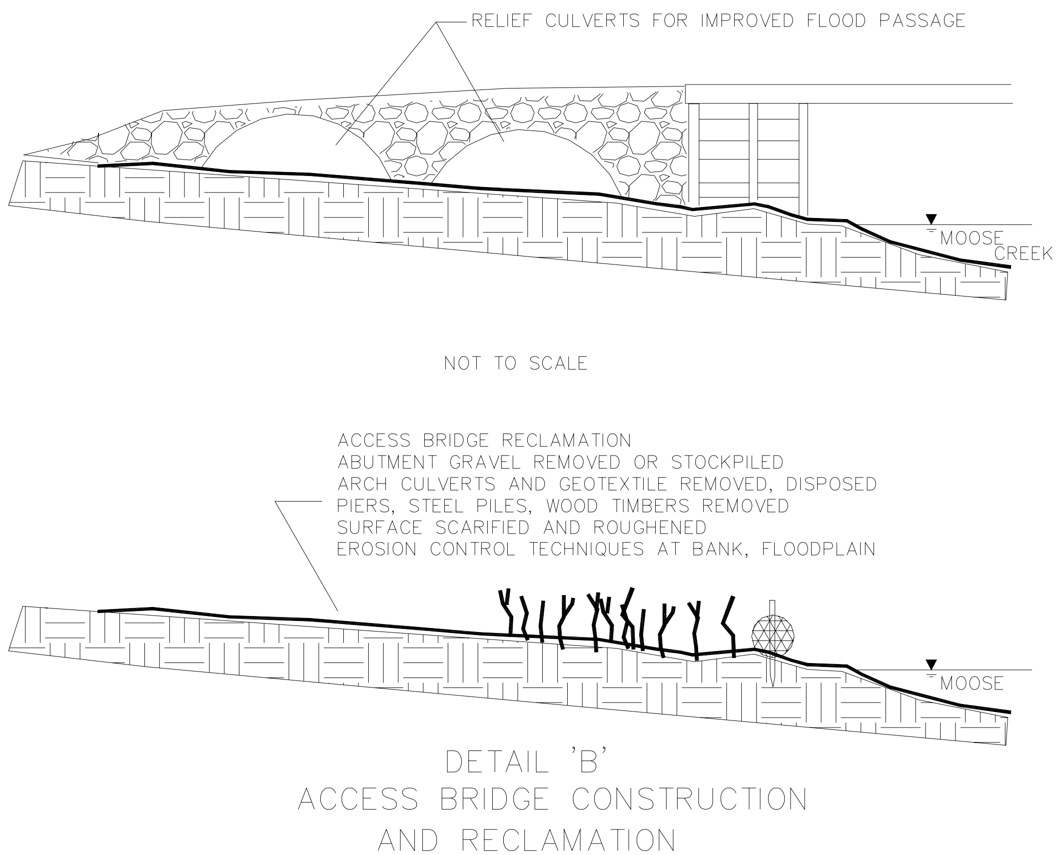

Figure 5. Detail 'B' showing relief culverts for bridge approach, and reclamation details.

Reclamation After Temporary Bridge Removal
If the bridge is to be a temporary structure, mitigation and reclamation activities will be required after the bridge removal. The bridge shall not be removed until all excavation and reclamation activities are completed at the DTK site, and all heavy equipment and supplies have been removed from the site.

All bridge components, including steel decking, girders, wood piles, and any associated concrete abutment pans will be completely removed from the area. Piles and piers in the channel should be removed by using a crane or hydraulic excavator, and lifting vertically from the channel. Similarly, any piles driven into the banks to construct bridge abutments will be removed. Gravel used for the bridge approaches will be excavated and removed; the right approach gravel may be removed entirely and stored at an off-site pit. The left approach gravel should be graded to match the reclaimed floodplain elevation and slope. Bioengineered erosion control methods shall be constructed as necessary through this area, to match methods used along the adjacent reclaimed channel banks and floodplains. Those methods are outlined in the following sections on Eldorado Creek and Moose Creek design.

PHASED GRAVEL EXCAVATION AND RECLAMATION

As described above, the clearing and gravel excavation operations should occur as a phased operation. Sequencing a construction project reduces the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle tracking, and will result in reduced sediment runoff. The suggested phased approach is to divide the area into three sections, each section approximately 15-20 acres in size (Figure 2).

Excavation

Using the phased approach, gravel excavation activities, preceded by site clearing, will occur initially in Area 1 only. Excavation should begin by removing the tailing piles and other areas of excess gravel which have been staked out, and moving the gravel to the process area. Gravel may be moved by pushing, loading and trucking, or using an earthmover. Gravel should be excavated down to the elevation determined by the site grading plan. In low-lying areas, gravel will be used to fill in depressions; in other areas, gravel will be used to create banks, floodplains, and other channel features as required by the design.

Reclamation

Once the desired gravel has been excavated and moved to the process area, and the area has been graded, reclamation activities can begin. The first step is to roughen the surface, which aids in the establishment of vegetative cover, increases infiltration, and provides for sediment trapping. Surfaces should be roughened using heavy equipment, including tillers or other suitable equipment. On flat surfaces, small furrows may be created using bulldozer tracks simply by driving the equipment in tight circles, with the blade up. On slopes, horizontal depressions should be created on the contour. The typical slope for most of the area will be graded to 2% (Figure 6). Contour furrows may be created on slopes up to 3:1, and may be from 10-40 cm deep.

After roughening, salvaged soil may be applied. Between 10-20 cm of salvaged soil should be spread over the site. Willow root wads and stems should be pushed into trenches and buried. Even though some compaction is necessary, earthwork should be conducted using a small bulldozer with low ground pressure tracks, to decrease soil compaction.

On areas where salvaged soil is not available, the graded areas should be seeded with legume and wheatgrass, as specified in Densmore et al. (2000). Following seeding and fertilizing procedures outlined in the manual, the site should be raked to hold the seeds in place and protect them from wind and water displacement.

Mulch may be applied to slopes steeper than 4:1 with more than 10 feet of vertical relief. The mulch is created at the site by chipping cleared alder. Mulch enhances plant establishment by conserving moisture, holding fertilizer, seed, and topsoil in place, and moderating soil temperatures. Mulch from alder will also act as a source for nitrogen. If the mulch is too thick, natural revegetation may be hampered, as seeds cannot get through the mulch layer to germinate.

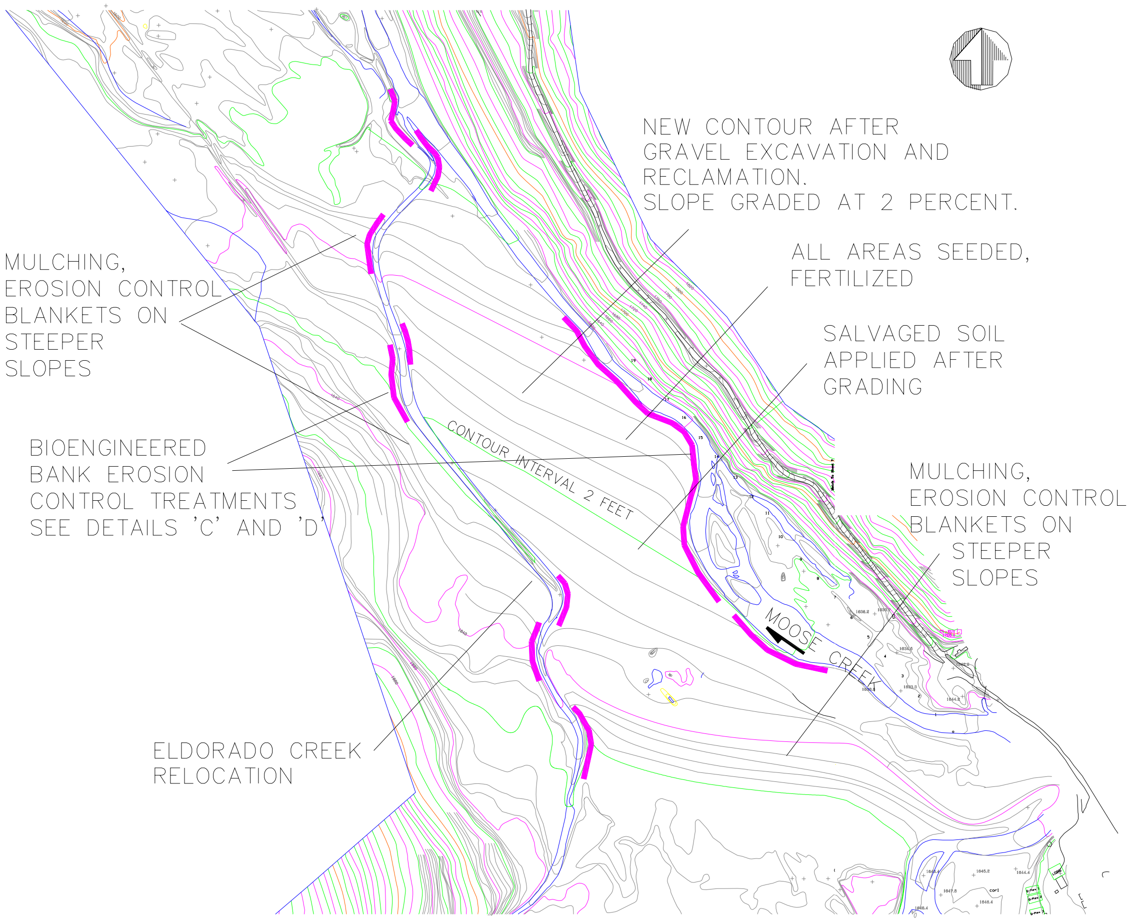

Figure 6. Reclamation details of Downtown Kantishna gravel pit.

Some areas of the DTK site will have slopes steeper than 3:1. For example, the left bank of the reconstructed Eldorado Creek, though not included in the gravel excavation plan, may be regraded to meet reclamation goals. Slopes greater than 3:1 will require additional erosion control methods to enhance revegetation and slope stability. For example, slopes from 3:1 to 2:1 should be treated as described above. However, after seeding and fertilizer application, an approved erosion control blanket should be installed if a mulch layer was not applied.

ELDORADO CREEK RELOCATION AND RECLAMATION

An integral part of the DTK plan is the relocation and reclamation of the reach of Eldorado Creek that flows along the western boundary of the proposed gravel pit. This channel has been moved and relocated a number of times due to placer mining operations and other activities on the former claims. Currently, the channel is unstable, with a non-functioning floodplain, poorly defined banks, numerous channel remnants, and assorted settling ponds scattered about the project area.

The object of the stream reclamation activities for Eldorado Creek is to improve riparian habitat through this reach, restore function to the channel and floodplain, and increase natural stability, which will increase the habitat and function of the surrounding area. The reconstruction of the stream reach will occur as an integral part of the gravel excavation and reclamation activities.

Relocation and reconstruction of the Eldorado Creek involves the actual construction of a stream channel. Heavy equipment will be used to cut a new channel for the water conveyance, based on an engineering design which will provide the new channel dimensions, including the channel width, depth, slope, sinuosity, and other channel geometry. Other channel parameters include the bed material. Because the Eldorado Creek channel will traverse areas which have been heavily mined and processed, it may be necessary to bring in new bed material of a particular size gradation.

Channel Design

Channel design is based on a complete hydrologic and hydraulic analysis of the Eldorado Creek watershed. The design process requires substantial knowledge of the existing system, and is beyond the scope of this report. Successful channel design is a combination of science and art, and requires a thorough understanding of fluvial process, morphology, and channel and meander geometry in order to predict the most effective design for long-term stability and function. The failure of designers and engineers to understand these processes results in frequent failure of many such projects.

There are two common methods for channel design. The first is based on a hydraulic analysis; the second is based on a geomorphic analysis, and relies on a nearby 'reference reach' to help establish channel geometry. Due to the substantial impacts most streams in the Kantishna Hills area have suffered as a result of long-term placer mining, unimpaired reference reaches are difficult to identify; as a result, previous stream channel design projects have relied primarily on a hydraulic design process, with some consideration of geomorphology. The hydraulic analysis process is briefly described below.

The requirements for channel design include a streambed capacity to contain a bankfull discharge, which is generally somewhere between a 1.5- and 2-year flood. The design process begins with the estimation of design flood flows from regional multiple-regression estimations. Values of bankfull discharge are often estimated in the field, though extensive disturbances such as found on Eldorado Creek may prevent an accurate estimation.

Based on the design discharge, hydraulic conveyance equations are applied to determine the preliminary estimates of channel geometry. In addition to channel capacity, the channel must be designed to be stable for both bed and bank. Design theory dictates that incipient motion of bed and bank materials begin at or just above bankfull discharge. In this manner, a general balance in bedload transport should be achieved. In flooding conditions, material being brought down from steeper reaches upstream should pass through to less steep reaches. At low flow, low shear stresses will not cause erosion, and no deposition will occur. A stable channel experiences some erosion and deposition occurring around a long-term average.

A similar design process occurs for the floodplain, which is designed to carry excess flows which spill out of the channel. Stream geomorphic parameters, such as sinuosity, beltwidth, and others may be checked using a stream classification system.

Channel Construction
Once the channel is designed, field preparations are conducted and coordinated with the gravel excavation activities. After clearing activities are completed for Phase 1, temporary relocation of the Eldorado Creek channel will be required to dewater the work site. Additionally, diversion of the creek will allow the reconstruction of the channel to be conducted in dry conditions, which will reduce sediment problems. Depending on project conditions, the new channel may be constructed at the start of the project, which will result in a short time that the creek is diverted, or at the conclusion of the gravel excavation activities, which may be more expedient, but will result in an increased risk to the water diversion activities.

Figure 2 shows the suggested placement of a temporary water diversion conveyance. The water may be diverted using several methods. The quickest method may be to dig a temporary ditch, from the Eldorado channel to Moose Creek, as shown in the drawing. The ditch should be sized to carry flood flows, and should be lined to minimize erosion and sedimentation problems. The lining may consist of sorted rock and gravel sized to resist being moved by the force of the water, or of a properly anchored geotextile. A second method to divert the water is to use large diameter HDPE pipe to carry the water. This will result in fewer sediment and erosion problems, but the pipe has to be installed properly, and sized to carry flood flows.

Once the water is diverted, new channel construction may begin. This will be accomplished using heavy equipment, including a hydraulic excavator and small crawler-dozer. Constant surveying and inspection will insure the channel design is implemented.

Stream Channel Erosion Control
An integral part of the channel design and construction for Eldorado Creek is the installation of bioengineered erosion control structures. These structures are designed to provide protection from water erosion to newly constructed ‘bare’ banks, before vegetation is established. Bioengineering techniques generally involve using a combination of materials to armor and protect stream banks, including vegetation (willow), root wads, toe rock, coconut fiber bio-logs (coir logs), and coir blankets.

The selection of appropriate techniques is dependent on site conditions, and the hydraulic parameters of the stream. Some techniques are designed to provide habitat, while others protect against scour from high shear stress forces. Though the final design for the Eldorado Creek channel may result in the selection of certain methods, certain techniques may be described that will most likely be utilized in this project.

Brush layering may be used along straight or gently curving reaches of the new channel. Brush layering is a technique which combines layers of dormant willow cuttings with soil to revegetate and stabilize the streambank. Branches are placed on horizontal benches that follow the contour of the slope and provide reinforcement to the soil. Two layers of a biodegradable fabric wrap are used to build soil lifts in between the layers of cuttings. Buried toe rock is used at the base of the brush layering to provide protection against scour. Coir erosion control blanket may be used on the adjacent floodplain.
For outside meanders in the new channel, coir logs should be used, in conjunction with a buried rock toe and willow cuttings. Coir logs are constructed of interwoven coconut fibers that are bound together with biodegradable nettings. Coir logs may provide more protection from erosive high water flows and ice damage than brush layering. Typical locations for these techniques are found in the drawings, along with a description of the construction methods (Figure 7).

Like any stream running through an industrial construction site, mitigative measures must be established to minimize sediment runoff into the new channel. Sediment control measures must be installed at the top of the banks, where the new channel traverses a cleared, newly excavated, or newly reclaimed slope. Silt fencing, and/or straw wattles, should be installed along the banks as part of the stream reconstruction project, before the stream flow is returned to the channel.

MOOSE CREEK BANK STABILIZATION

A key component of the DTK project includes the stabilization and restoration of the Moose Creek floodplain adjacent to the project area. The banks are currently unstable, with sections of missing riparian vegetation. As a result of placer mining activities, several low water fords are located along this reach of Moose Creek, and the channel has widened and slightly braided in one section. The gravel excavation area is located to the west of the left bank of Moose Creek. Excavation and reclamation activities will include the construction of bioengineered bank erosion control structures, along both banks of Moose Creek. The goal is to restore the attributes of floodplains which contribute to ecosystem quality. These include soils, vegetation, wildlife habitat, dissipation of flood energy, sedimentation processes, and ground water (including riparian ground water) recharge.

Proper hydrologic function for the channel and floodplain is dependent upon channel geometry. In order to increase stability and provide riparian habitat, it may be necessary to shape the channel and establish floodplain elevation through the addition of gravel.

Hydraulic Analysis

Determining the required elevation for proper floodplain function is a matter of hydrologic and hydraulic analysis of the Moose Creek channel. Stated simply, the active channel of a stream can be generally considered to carry up to about a 1.5 to 2-year flood event before overtopping onto the floodplain. In other words, any flood event larger in magnitude than a 2-year flood should spill out over the banks and onto the floodplain. A simple analysis using contour maps through this reach shows that the difference in height from the low water line (map blue line) to the top of the channel is approximately 5 feet in undisturbed

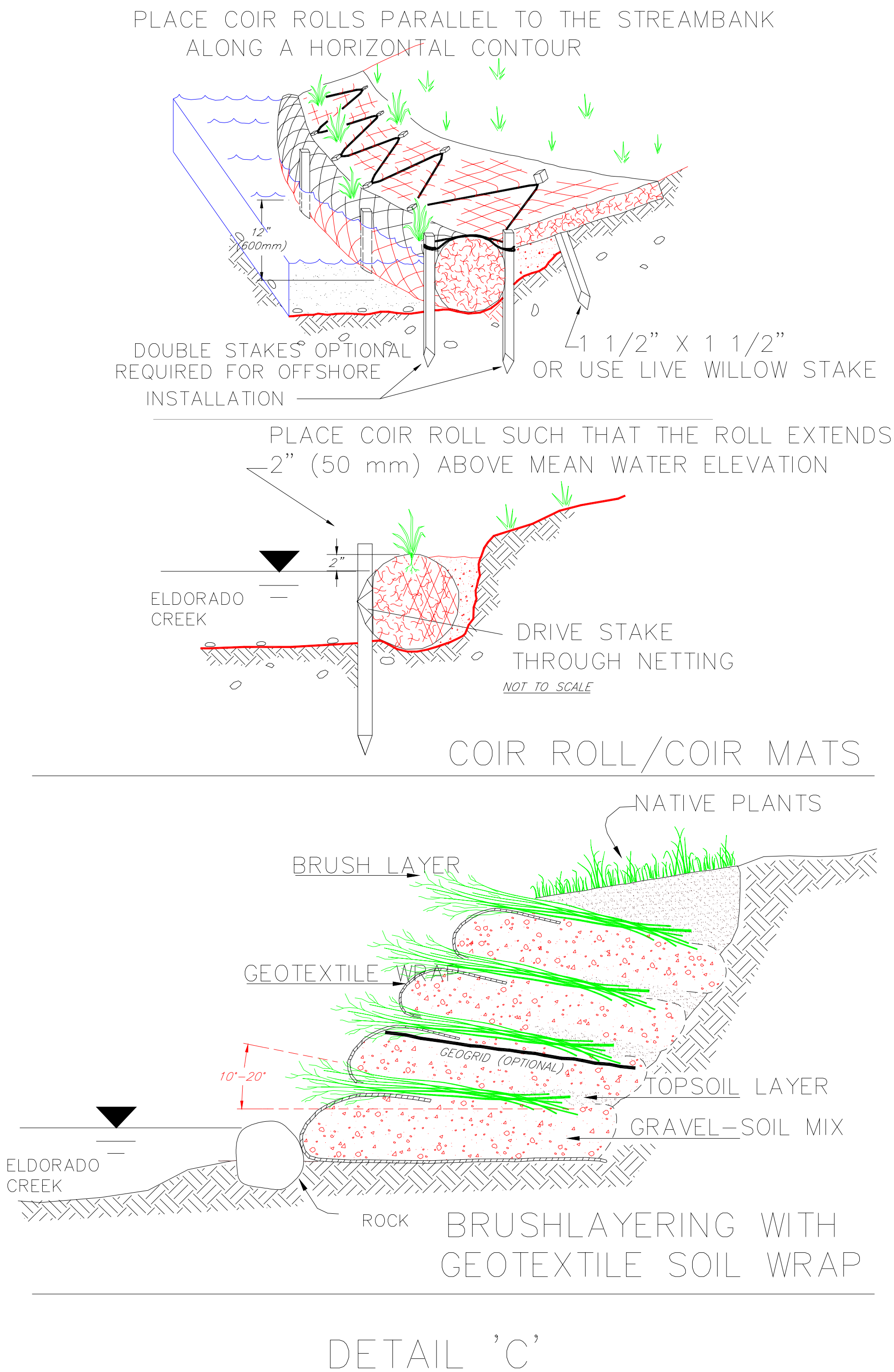

Figure 7. Typical bioengineered bank erosion control methods for Eldorado Creek reclamation.

areas. This height, plus an additional depth of 1 foot for organic overburden material, was used in a previous analysis to estimate the proper height of the Moose Creek floodplain.

That figure was then used to determine how much gravel was available for excavation, and how much was needed for bank protection and floodplain reclamation. Final approval of this plan will require a thorough hydraulic and geomorphic analysis of the Moose Creek reach, to determine channel configuration and floodplain elevations.

Stream Channel Erosion Control

An integral part of the channel design and construction for Moose Creek is the installation of bioengineered erosion control structures. These structures are designed to provide protection from water erosion to newly constructed 'bare' banks, before vegetation is established. Bioengineering techniques generally involve using a combination of materials to armor and protect stream banks, including vegetation (willow), root wads, toe rock, coconut fiber bio-logs (coir logs), and coir blankets. An example of root wad construction is found in Figure 8.

The selection of appropriate techniques is dependent on site conditions, and the hydraulic parameters of the stream. Some techniques are designed to provide habitat, while others protect against scour from high shear stress forces. Though the final design for the Moose Creek channel may result in the selection of certain methods, certain techniques may be described that will most likely be utilized in this project.

Brush layering may be used along straight or gently curving reaches of the new channel. Brush layering is a technique which combines layers of dormant willow cuttings with soil to revegetated and stabilize the streambank. Branches are placed on horizontal benches that follow the contour of the slope and provide reinforcement to the soil. Two layers of a biodegradable fabric wrap are used to build soil lifts in between the layers of cuttings. Buried toe rock is used at the base of the brush layering to provide protection against scour. The locations for this technique are found in the drawings, along with a description of the construction techniques.

Root wads are a streambank protection technique that provides immediate bank stabilization, protects the toe of the slope, and provides fish habitat. Root wads, when installed correctly with proper toe scour protection, are well suited for higher velocity river systems and riverbanks which are severely eroded. Root wad structures should be designed by an experienced hydraulic engineer with experience in design and installation, as buoyant forces and toe scour can result in structural failure in flooding conditions. The locations for this technique are found in the drawings, along with a description of the construction techniques.

Mitigative measures must be established to minimize sediment runoff into Moose Creek. Sediment control measures must be installed at the top of the banks, where new floodplains have been constructed, either by excavation or fill. Silt fencing, and/or straw wattles, should be installed along the banks as part of the bank stabilization project.

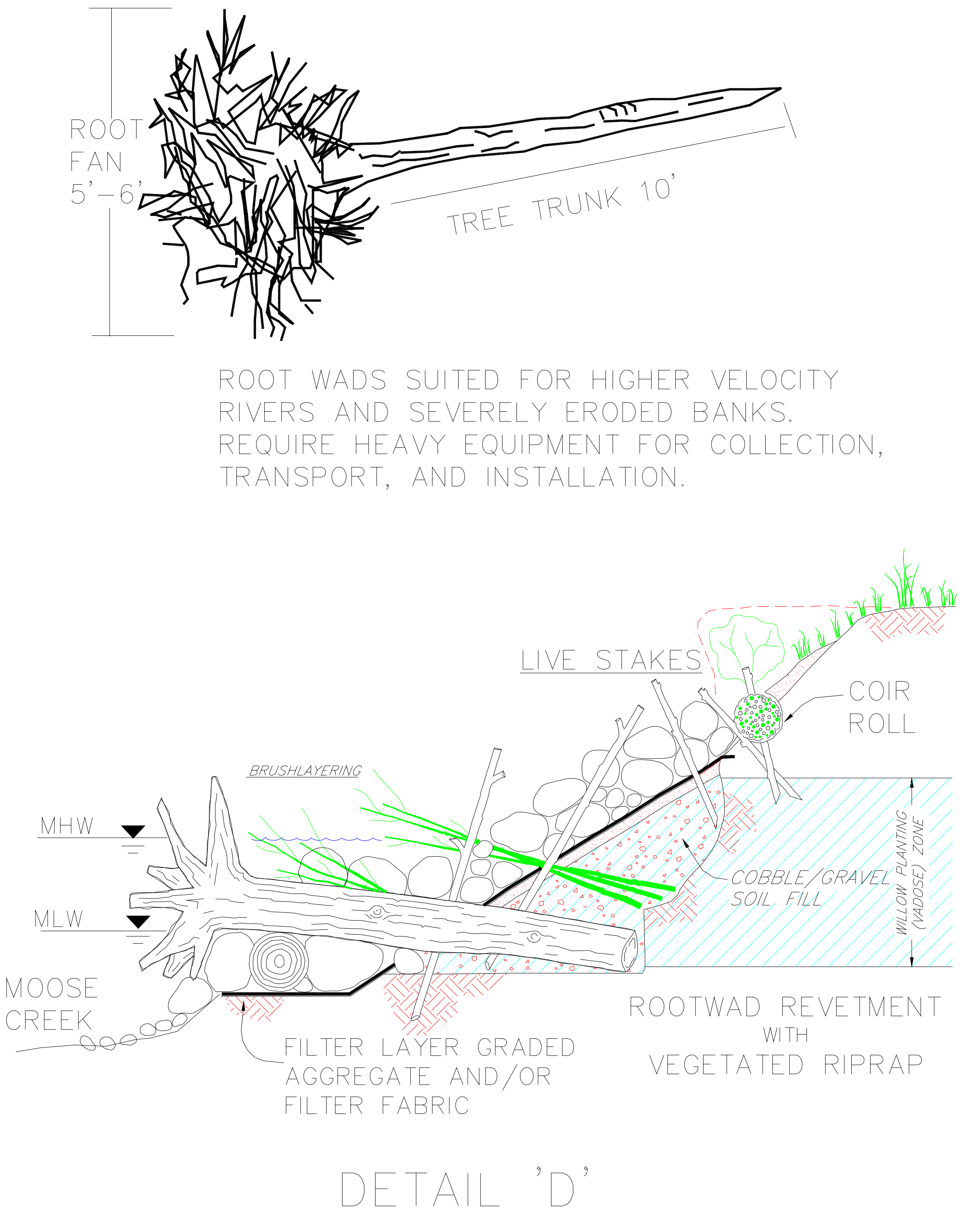

Figure 8. Typical bioengineered bank erosion control methods for Moose Creek reclamation.

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